XII. *Contributions to a Knowledge of the Structure and Biology of some Indian Insects.*—II. *On* Embia major, *sp. nov., from the Himalayas. By* A. D. Imms, *B.A., D.Sc., F.L.S., Forest Zoologist to the Government of India and Fellow of the University of Allahabad.*

(Plates 36–38 and 6 Text-figures.)

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Contents.

		Page
1.	Introductory Remarks	167
2.	Description of the Male	169
3.	Description of the Female	177
4.	Comparison of the Differences between the Sexes	179
5.	Systematic Position of the Species	180
6.	The Ova	180
7.	The Newly Hatched Larva	182
8.	The Second Stage Larva	182
9.	The Half-grown Larva	183
10.	The Male Nymph	183
11.	The Female Nymph	184
12.	Observations on the Biology of the Species	184
13.	Summary of Conclusions	191
14.	Bibliography	192
15.	Explanation of the Plates	194

1. Introductory Remarks.

The Embiidæ form a small and well-defined group of Insects of very wide distribution. In their range they are almost cosmopolitan, being absent only from the polar and cooler temperate regions of the earth. They exhibit a remarkable simplicity and uniformity of structure which are partly due to primitive features in their organization, and to the fact that certain other characters have been probably secondarily acquired through degeneration. They further exhibit in almost all of the species very marked sexual dimorphism. It has long been known that the individuals of both sexes have the faculty of secreting silk, with which they manufacture the tunnels constituting their nests. That the Embiidæ are an ancient group, and now long past the zenith of their prime is probable. In this respect they are worthy of comparison with *Peripatus* and *Anaspides* among other Arthropods.

The described species of Embiidæ are about sixty in number, the exact figure depending upon the validity of certain specific names. So far as I have been able to ascertain, forty-two of these species have been based upon an acquaintance with one sex only, thirty-nine being founded on male examples and three on female. From this it is evident that in only 18 species, or 30 per cent. of the total number of known species, have both sexes been described. Among the Embiidæ in particular, unless both sexes happen to be taken in association with one another, it becomes a matter of great difficulty afterwards to correlate a particular male with any particular female. Owing to this cause, and also to the fact that both immature and mature winged examples are frequently taken, a good deal of uncertainty exists at present with regard to several species. The unsuspected discovery that, in at least four species, the males are dimorphic, further complicates matters. As additional species become known, these difficulties are liable to result in the synonymy of the Embiidæ becoming complexly involved. It is therefore imperative, in my opinion, that entomologists should refrain as far as possible from describing new species of Embiidæ based upon one sex only.

In the case of the males, the best and most constant characters are those afforded by the structure of the two terminal segments of the abdomen. The gratitude of all students of the Embiidæ is due to Enderlein, who is the first investigator to attempt systematically to study this region of the body. His recent monograph (1912) for this reason makes a most important advance in our knowledge of the group.

Hitherto only four species of Embiidæ have been recorded from India, and all pertaining to the genus *Oligotoma*, Westw., viz.:—

O. latreillii, Rambur, Hist. Nat. Neurop. 1842, p. 312. Bombay.
O. michaeli, MacLachlan, Journ. Linn. Soc. Lond., Zool. vol. xiii. (1877) p. 383, pl. 21. figs. 1–3. Umballa and Calcutta.
O. bramina, Saussure, Mitt. Schweiz. Ent. Ges. ix. (1896) p. 352. Bombay.
O. saundersi, Westwood, Trans. Linn. Soc. Lond. vol. xvii. (1837) p. 373, pl. 2. figs. 2, 2 *a–f*. Jubbulpore, Calcutta, and Pusa.

Whether these four names represent four separate and distinct species is extremely doubtful. Enderlein (1912) regards *O. bramina* as being a synonym of *O. michaeli*, while Krauss (1911) in his "Monographie der Embien" considers them to be two species. On the other hand, Krauss regards *O. latreillii* as being a synonym of *O. saundersi*.

Embia major is remarkable in being by far the largest species of Embiidæ yet discovered.

The genus *Embia*, Latr., furthermore, has not previously been known to occur in any part of the Oriental zoo-geographical region. In the bordering countries of the Palæarctic region three species of the genus, however, are known to occur, viz.:—

E. persica, MacLachlan, Journ. Linn. Soc. Lond., Zool. vol. xiii. (1877) p. 382. North Persia.
E. mauritanica, Lucas, Explor. Sci. Algérie, vol. iii. Neur., 1849, pp. 111–114, figs. 2 *a*–2 *n*. Syria. (Also recorded from Algeria, the Canary Isles, and British East Africa.)
E. tartara, Saussure, Mitt. Schweiz. Ent. Ges. ix. (1896) p. 352. Turkestan.

In July 1909 I had the good fortune to meet with two large male Embiids belonging to the species herein described for the first time. They occurred among herbage growing along the sides of a rivulet, at an altitude of 4600 feet, in the Naini Tal district, in the Himalayan foot-hills of Kumaon. Since that time, I have visited various parts of the same district at different times of the year, and have been successful in also procuring the female, the eggs, and the silken nests of the insect in comparative abundance. I was thus enabled to make a more extended series of observations on the habits and post-embryonic development of a single species of Embiidæ, than has fallen to the fortune of previous students of the group.

2. Description of the Male.

Deep brown-black, clothed with dark brown or almost black hairs. The antennæ 20–29-jointed, a little shorter than the combined length of the head and thorax. The head, thorax, and abdomen mutually related in length in the proportion of 3 : 5 : 8. The first joint of the hind tarsi with two arolia. The 10th tergum completely divided into a pair of plates, the right being considerably larger than the left. The left plate produced into a stout curved process; the process of the right plate only represented by a minute papilla. The process of the 9th sternum large, curved at the apex only. Basal joint of the left cercus much enlarged, conical; its proximal surface armed with numerous minute scattered denticles. Distal joint of both cerci similar to one another. Upper wing 8·5–11·25 mm. long, 2·75–3·5 mm. broad; lower wing 8–10·5 mm. long, 2·5–3·5 mm. broad.

Length 12·75–18 mm.

The Head.—The head is longer than broad with the posterior margin rounded; it attains its greatest diameter between the eyes. It is uniformly clothed with longish, almost black hairs. The *eyes* are only partially visible from above, reniform in shape, and have their concave side closely embracing the basal joint of the antenna.

The *labrum* is much broader than long, with its anterior angles prominently rounded (Pl. 38. fig. 8). It presents no special features. The *epipharynx* is represented by a longitudinal row of setæ on either side of the pharyngeal surface of the labrum. These setæ are most probably sensory in function. The *clypeus* is larger than the labrum and is divided into a membranous *ante-clypeus* (*a.cl.* in fig. 8), and a wider and fully chitinised *post-clypeus* (*p.cl.*), which articulates with the epicranium just in front of the bases of the antennæ.

The *antennæ* vary in length from 6–7·5 mm. and are larger than the thorax, but a little shorter than the combined length of the head and thorax. The number of joints varies between 20 and 29, the most usual number being from 23–27. More than half the individuals examined had one or both of their antennæ imperfect. The basal joint (Pl. 38. fig. 2) is the widest, and the third joint the largest; the succeeding joints differ very little individually among themselves. The combined length of the 4th, 5th, and 6th joints exceeds that of the first two joints.

The *mandibles* (Pl. 38. fig. 5) are slender, considerably longer than broad, and much less massive than those of the female. They are armed with two very small apical teeth placed side by side, and there are no other definite teeth. Below the apex of each mandible the inner margin is produced for less than half its length into a sharp cutting-edge. The inner angle of each mandible is somewhat produced, and to it is attached the tendon of the *adductor muscle* (*add.*).

The *ginglymus* (*ging.*) is directed obliquely outwards and lies above and partly behind the *condyle* (*cond.*). To the outer angle of each mandible is attached the tendon of the *abductor muscle* (*abd.*), but there is no special process developed.

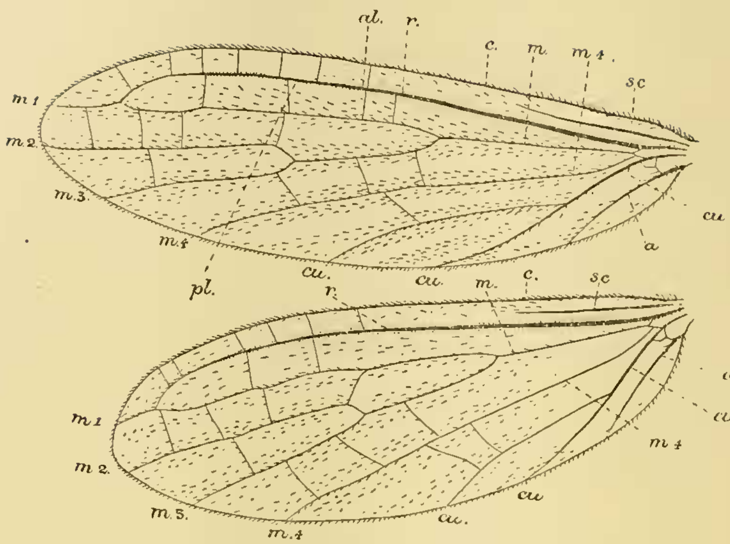
The *first maxillæ* each consist of a five-jointed palp, a membranous galea, and a stout lacinia, carried by the cardo and stipes (Pl. 38. fig. 11). The joints of the *palpi* are related to one another in length in the proportion of 17 : 9 : 15 : 18 : 22,—the second joint being much the shortest and the apical joint the longest. The *galea* (*gal.*) is membranous and unarmed. The *lacinia* (*lac.*) is strongly chitinised and armed with a pair of small apical teeth situated side by side; along the inner margin of the lacinia is a row of stiff elongate setæ. The *cardo* (*car.*) and *stipes* (*st.*) present no special features; the former is the larger of the two joints.

The *second maxillæ* (*labium*) consist of a quadrangular *submentum* (m_2 in Pl. 38. fig. 9), a well-developed *mentum* (m_1). They differ considerably in form from those figured by Grassi and Sandias (1897, pl. 19. fig. 7) for *Haploembia solieri* (Rambur).

Arising from near the base of the submentum are the *labial palpi* (*l.p.*), which are three-jointed. The joints are related to one another in length in the proportion of approximately 12 : 14 : 17. In some specimens, however, the two basal joints are practically equal in size. A vestigeal *palpiger* is present, and its limits are indicated by an indistinct suture (*pgr.*). Distally, the mentum carries a pair of large external lobes or *paraglossæ* (*g.*), which are the counter-parts of the galeæ of the 1st maxillæ. Situated on either side of the median line, and between the paraglossæ, are a pair of small pointed lobes representing a divided ligula (*l.*) and corresponding to the *laciniæ* of the 1st maxillæ. The *mentum* exhibits indications of a paired formation being divided into halves by an indistinct median line which is much less chitinised than the rest of the sclerite. The *hypopharynx* appears as a median projection from the floor of the mouth. Viewed from above it appears quadrangular in form, and longer than broad. Its dorsal surface is invested with a covering of extremely minute scales, which are pectinate along the distal margin. In many instances the middle tooth of each scale is prolonged into a slender spine. On the ventral surface of the hypopharynx the scales become less numerous and disappear. Such scales have also been noted and figured by Enderlein (1909, p. 168, fig. 3) in *Oligotoma saundersi*, Westw., who regards them as taste-scales.

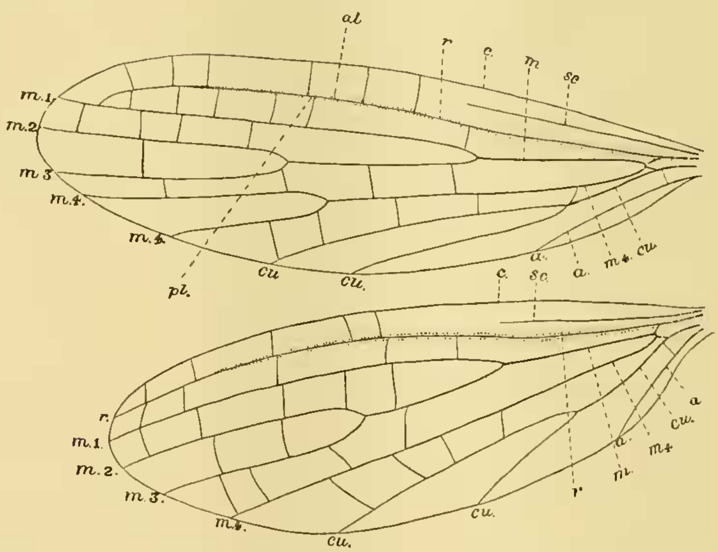
The Thorax.—The *prothorax* is narrower than the head, sub-quadrate, but slightly broader than long. Its anterior margin is straight and the sides slightly diverge posteriorly. The hind margin is produced into a median convexity (Pl. 37. fig. 1). The anterior fourth of the tergum is definitely constricted off from the rest by means of a deep transverse sulcus. At right angles to the latter and terminating in it anteriorly, is a shallow median longitudinal groove. Both the anterior margin and the sides are clothed with stiff black hairs. The *mesothorax* is the largest division of the three, subquadrate in shape, slightly broader than long, and wider than the prothorax. Its anterior margin is clothed with pilose hairs. The *metathorax* is entirely glabrous and a little shorter than the mesothorax. The *fore-wings* vary in length from 8·5–11·25 mm., and their breadth varies from 2·75–3·5 mm. The *hind-wings* vary from 8–10·5 mm. in length and 2·5–3·5 mm. in breadth. The length of the wings compared with that of the abdomen exhibits a certain amount of variation in different individuals. In some examples the apices of the closed wings extend a little beyond the tips of the cerci, while in other specimens they only reach far enough posteriorly to cover a portion of the basal joint alone of each cercus. The *neuration* exhibits a very wide range of individual variation, especially as regards the transverse veins, and, furthermore, the veins of the right and left wings frequently differ from one another. If examined immediately after the last ecdysis, the wings are seen to be hyaline and the veins are more clearly exhibited. When the full darkening of the chitin is attained the veins are reduced to the condition of being merely darker lines of thickened cuticle following the original neuration. A comparison of the wings in the hyaline and fully developed conditions, shows that the neuration undergoes practically no reduction or modification during the period taken by the wing-membranes to harden and mature. In some specimens, however, certain of the longitudinal veins exhibit a tendency to dwindle away at their apices, before quite reaching the margin of the wing. In this respect *Embia major* is an example of the first step in the reduction of the wing neuration, which attains its maximum in the genus *Oligotoma*. The surface of the wings is clothed with minute pilose hairs together with longitudinal rows of longer hairs. These latter are disposed along the courses of the veins and in the areas between the veins (text-fig. 1), but are entirely wanting from the hyaline longitudinal areas of the wing-membrane. The margins of the wings are fringed with regularly arranged longish setæ. In the text-figure the neuration of an average specimen is represented. The terminology followed is that advocated by Comstock and Needham (1898, p. 423), which is based on a study of the phylogenetic development of the wing-veins of Insects. The *costal vein* (*c.*) is confluent with the anterior margin in both pairs of wings. The *subcostal vein* (*sc.*) is short, being less than one-third of the length of the wing; it tapers to a point and dwindles away altogether. This vein is thickly chitinised, and just visible to the unaided eye. The *radial vein* (*r.*) is the most conspicuous vein of all, being very strongly chitinised and much thickened in calibre. Running parallel to, and almost in contact with the anterior and posterior margins of the radial vein, are a pair of very fine dull red lines (*al.* and *pl.* in text-fig. 1). These two lines terminate a short distance before reaching the junction of the radial and median veins. They are termed by Enderlein (1912, p. 10) the "*Radiussaumlinien*" (*Radiolimbolarien*), and by Krauss (1911, p. 7) the "*Radius-Nebenlinien.*" They possess a certain amount of value as a specific character, and may be conveniently referred to as the *anterior* and *posterior radial lines*. A short distance before reaching the apex of the wing the radial vein joins the median. A variable series of 4–7 transverse veins, situated in the distal half of each wing, unite the costal with the radial vein. The *median vein* and its branches are distributed over about one-half the total area of each wing

Text-fig. 1.



Neuration of the upper and lower wings of a typical specimen of *Embia major* (slightly diagrammatic).—*c.*, costal vein; *sc.*, subcostal vein; *r.*, radial vein; *al.*, anterior radial line; *pl.*, posterior radial line; *m.*, upper stem of radial vein; $m._1$, $m._2$, $m._3$, branches of the upper stem of the radial vein; $m._4$, lower stem of radial vein; *cu.*, cubital vein and its branches; *a.*, anal vein. The courses of the *anterior* and *posterior radial lines* in both wings are represented by the dotted lines. × 9. (Westwood Bequest.)

Text-fig. 2.



The probable neuration of the ancestral type from which *Embia major* has originated. This conclusion is arrived at by combining in one figure the variations exhibited in different individuals, and also the condition of the neuration seen immediately after the last ecdysis. (Reference lettering as in text-fig. 1.) × 9. (Westwood Bequest.)

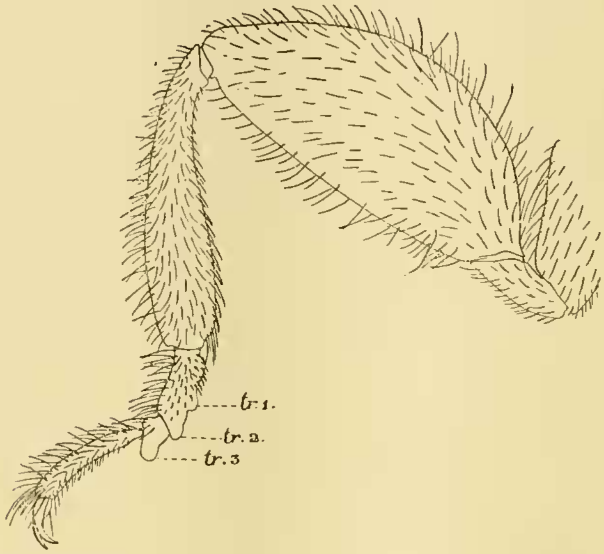
(m, m_1–m_4 in text-figs. 1 and 2). It consists of two main stems (m and m_4) arising close together at the base of the wing. The upper stem bifurcates into two branches before reaching the middle of the wing. The upper branch (m_1) remains undivided and receives the apex of the radial vein. It is, furthermore, united to that vein by a series of 4–6 cross-veins. The lower branch divides into two veins (m_2 and m_3): the upper vein m_2 is connected with m_1 by a variable series of cross-veins; the lower vein m_3 is united to m_2 by one or two cross-veins. The lower stem of the radial vein (m_4), as a rule, remains undivided; in the left upper wing of one specimen, however, it was found to be bifurcated (*vide* text-fig. 2). It is joined to the veins in front by 3 or 4 transverse veins, and to the cubital vein behind by 1–4 similar veins. The *cubital vein* (*cu.*) bifurcates at a distance from its origin equal to about one-third of its length. The upper branch is joined to the median vein by the cross-veins just referred to; the lower branch does not receive any cross-veins, but is greatly thickened and chitinised like the radius, and clearly visible to the unaided eye. The *anal vein* (*a.*) is the smallest vein of all and is unbranched; it is connected with the basal stem of the cubital vein by a single transverse vein. Enderlein, however, remarks:—" Die Analis is die zarte und hyaline Clavusnaht, die Axillaris läuft in der Mitte des Clavus kräftig und endet ohne Nodulus-bildung vom Ende des Clavus in den Hinterrand " (1912, p. 10). This interpretation I believe to be incorrect, for " Nähte " occur between other veins also, and can be seen in the newly formed wing immediately after the last ecdysis, before full chitinisation has taken place. The vein which appears to me to represent the true anal vein is the one he terms the axillary. In text-fig. 2 are represented the greatest number of veins that could *ex hypothesi* occur in any individual pair of wings. It has been constructed by combining in one figure the various variations that I have observed in both pairs of wings of eight individual males. The neuration of the upper wing shown in the figure agrees almost entirely with Krauss's figure (1911, p. 7) of the primitive hypothetical state of wing-neuration in Embiidæ, the only difference being the much greater number of transverse veins in *Embia major*. In the bifurcation of the lower stem (m_4) of the radial vein, as an occasional and apparently rare variation, we have a relic of an earlier condition. So far as I am aware, this only occurs as a constant character in the genus *Donaconethis*, Enderl., where it is present in both wings. Krauss (1911, Taf. 5. fig. 21 *d*) figures the right wings of a specimen of *E. savignyi*, Westw., in which the vein m_4 is similarly bifurcated, though it is not usually so in that species. In the lower wing of one specimen of *E. major* the radial vein passes directly to the margin of the wing, instead of uniting with the upper stem (m_1) of the median vein. This appears to be a reversion to a primitive condition which is found in the generalised genus *Clothoda*, Enderl., and one or two other forms.

The *legs* do not present any special features, with the exception of the *arolia* * or ventral pads of the tarsi. In relation with the hind pair of legs there are two such pads on the first tarsal joint (metatarsus), and in this respect *E. major* differs from its congeners and resembles the genus *Haploembia*, Verh. On the second tarsal joint there

* " Sohlenbläschen " of Verhoeff.

is a single pad, as is usual among Embiidæ (text-fig. 3). The arolia on both joints of the tarsi are completely glabrous. The *tarsal claws* (Pl. 38. fig. 13) of each pair of legs do not differ from one another in any essential points. Each claw is broad at the base, but narrows and becomes acuminate at its distal half. It carries a stiff obliquely-directed *seta*, which arises from the basal portion of the claw.

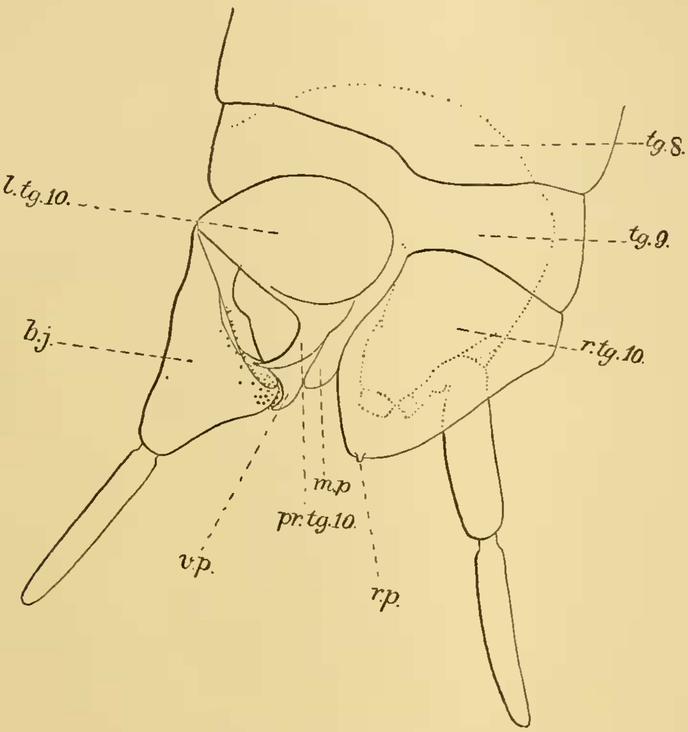
Text-fig. 3.



The right hind leg of the male, viewed from the outer aspect. *tr.* 1 and *tr.* 2, arolia or ventral pads of the first tarsal joint (" metatarsus "); *tr.* 3, arolium of the second tarsal joint. × circa 22. (From a preparation mounted in Canada balsam.) (Westwood Bequest.)

The Abdomen consists of ten terga, of which the first eight are almost glabrous. The pleura and the 9th and 10th terga are provided with brownish hairs. The first seven terga are subequal, the eighth is shorter than those of any of the preceding segments, and the ninth is asymmetrical and the smallest of all: it appears as if compressed between the 8th and 10th segments, and partly distorted in consequence, so that the right portion appears somewhat larger than the left (Pl. 37. fig. 3, $tg._9$). The tenth tergum is completely divided into right and left plates, the right being larger than the left. The left plate is produced posteriorly into a stout curved process (*pr.tg.* 10 in text-fig. 4); the process of the right plate is only represented by a minute papilla (*r.p.*). The left-hand portion of the right plate (*m.p.* in text-fig. 4) is marked off by means of a suture from the rest of the plate. Ventrally, the abdomen consists of nine evident sterna. The first sternum is extremely small and firmly soldered to the posterior margin of the metathorax. The 2nd–8th sterna differ but little among themselves, the 2nd, 3rd, and 4th being somewhat longer than the succeeding sterna. The ninth sternum is the largest of all; it is asymmetrical, and forms the *subgenital plate*; it appears to be formed by the fusion together of the ninth sternum and the right plate of the tenth sternum. Whether the left-hand portion of the tenth sternum of the nymph participates also in its formation, is extremely doubtful. From a prolonged study of the insect, in different stages of development, I have come to the conclusion that the left plate of the 10th sternum becomes modified, but persists as *ventral process* (*v.p.* in Pl. 37. fig. 3 and in text-fig. 4). This process is hinged to the subgenital plate, and is attached to it in the large posterior

Text-fig. 4.



The three terminal abdominal segments of the adult male, viewed from the dorsal side. *b.j.*, enlarged basal joint of left cercus; *pr.tg.* 10, process of the left 10th tergal plate; *m.p.*, median plate; *r.p.*, vestige or rudiment of the process of the right 10th tergal plate; *l.tg.* 10, left tergal plate of the 10th segment; *r.tg.* 10, right tergal plate of the 10th segment; *tg.* 8, tergum of 8th segment; *tg.* 9, tergum of 9th segment; *v.p.*, "ventral process," which is probably formed from the left sternal shield of the 10th segment of the larva and nymph. × circa 28. (From a specimen treated with potash and mounted in Canada balsam.) (Westwood Bequest.)

concavity, which is shown in Pl. 37. fig. 2. Krauss, however, regards this structure as the "Grundplatte" (basal plate) of the left cercus (1911, p. 12). Enderlein (1912) describes it as the "Anhang" of the ninth sternite, which is in accordance with the morphological explanation suggested above.

The basal joint of the left cercus is sub-conical in shape (Pl. 37. figs. 2 & 3, and text-fig. 4). Its greatest diameter is at the proximal end and measures double that of the corresponding joint of the left cercus. The proximal surface is excavated to form a prominent concavity (fig. 2), over which are distributed a number of small denticles (text-fig. 4). The inner wall of the concavity is strongly rounded and is situated beneath the ventral process already referred to. The distal joints of both cerci are elongate and cylindrical, and similar one to the other.

Coloration.—Seen from the dorsal side, the head, together with its appendages, the legs, the terminal and penultimate segments of the abdomen, and the cerci except at their apices, vary in coloration from deep brown-black to black, with pruinose reflections. The prothorax varies from chestnut-brown to black, but in most specimens it is usually brown-black in colour. The remaining thoracic and abdominal segments are dark pruinose-brown. The claws of the feet are yellowish-white, but fuscous distally. The articulations between the joints of the legs, of the tarsi except the first pair, of the antennæ, and of the labial and maxillary palpi are cream-coloured. The ante-clypeus is usually light brown and very conspicuous for that reason, and the apices of the cerci are yellowish-white or cream-coloured. The intersegmental regions between the head and the prothorax, and between the prothorax and the mesothorax are well defined, membranous, and yellowish-white in colour. The pleuræ of the metathorax and the fist eight abdominal segments are similarly membranous, and form a whitish sinuous line along each side of the body, but are less conspicuous than in the female.

Ventrally the coloration is very much the same as it is dorsally. The cervical region is a very conspicuous, yellowish-white, membranous area, and the region between the prothorax and mesothorax is similarly membranous.

The wings are fuscous, striped with a series of longitudinal hyaline areas (Pl. 37. fig. 1). These areas have a definite arrangement with reference to the various longitudinal veins, and are, furthermore, devoid of the longer setæ which are distributed over the rest of the wings. As already mentioned (p. 171) the newly formed wing, after the last ecdysis, is at first hyaline, the darkening and full chitinisation taking place subsequently, leaving only these longitudinal areas unaltered. The latter remain unmodified and undarkened throughout life. In this connection it is worthy of note that Wood-Mason (1883, p. 633) suggested that these areas represent the original hyaline colour of the wings; and it gives me great pleasure in being able to confirm his suggestion. The hyaline areas are disposed in the following manner:—(*a*) An extremely narrow strip bordering both the anterior and posterior radial lines (p. 171); (*b*) a prominent area situated midway between the two branches m_1 and m_2 of the median vein; (*c*) a short area lying between the two veins m_2 and m_3, formed by the division of the lower branch of the upper stem of the median vein; (*d*) a very long and conspicuous area situated about midway between the two stems m and m_4 of the median vein and extending outwards so as to almost reach the outer margin of the wing; (*e*) a very similar area situated between m_4 and the cubital vein; (*f*) one or two very short lines lying within the fork formed by the bifurcation of the cubital vein; (*g*) a short area between the much thickened stem of the cubital vein and the anal vein. In those cases where the lower stem m_4 of the median vein is bifurcated, an additional hyaline area is present between the two branches of the fork. This, however, is a rare variation. At the points where certain of the transverse veins cross the hyaline areas (Pl. 37. fig. 1) they become bordered with a minute hyaline strip, producing the appearance of cross-pieces on the wing-membrane.

3. Description of the Female.

Deep brown to brown-black, clothed with lighter brown hairs, longer and more numerous than in the male. The antennæ 23–29-jointed, shorter than the thorax. The head, thorax, and abdomen mutually related in length in the proportion of 3 : 7 : 10. The first joint of the hind tarsi with two arolia. The 8th and 9th abdominal terga subequal, but shorter than those of any of the preceding segments. The 10th tergum longer than the ninth, narrowing posteriorly with the hind margin prominently rounded.

Length 14·75–20·75 mm.

The Head differs from that of the male in that it attains its maximum width just behind the eyes. The *eyes*, moreover, are smaller and less markedly reniform. The *antennæ* (Pl. 38. fig. 3) measure from 5–6 mm. in length, and are shorter than the thorax. The number of joints varies from 23–29 and, for the most part, they are shorter and more annular than the corresponding joints in the male. The combined length of the 4th, 5th, and 6th joints is less than that of the first two joints. The *labrum* only differs from that of the male in that the hairs of the *epipharynx* are more numerous and rather more elongate; they are similarly disposed in two longitudinal rows as in the male. The *mandibles* (Pl. 38. fig. 6) are much more massive than in the male, and their biting-edges are armed with four prominent teeth (1–4 in fig. 6). Two of the teeth are situated close together at the apex of the jaw. These are followed by a large and usually bilobed tooth, occupying the middle of the biting-edge of the jaw. Near the inner angle there is a fourth and somewhat smaller tooth which in some individuals is greatly reduced or absent entirely. Immediately below this tooth (no. 4) is a basal process (*add.*) which provides attachment for the *adductor muscle* of the mandible. The *ginglymus* (*ging.*) is very prominent and is produced outwards on a stout pedicel. To the outside of the ginglymus is the *condyle* (*cond.*), and at the extreme outer angle of the mandible is situated the point of attachment of the *abductor muscle* (*abd.*). The *first maxillæ* only differ from those of the male in that the two apical teeth are considerably longer and more prominent. The dorsal tooth is rather longer and more slender than the ventral one. The *maxillary palpi* are five-jointed, and exhibit no appreciable differences in the two sexes. The *hypopharynx*, in the majority of specimens examined, was found to be slightly larger than that of the male, but does not appear to exhibit any essential differences.

The Thorax is longer than in the male, and consists of three annular segments whose terga are extremely simple in structure, differing but little from those of the abdomen except in size. The deep transverse suture of the prothorax is situated, in some specimens, rather further forward than in the male. The median longitudinal groove is frequently produced beyond the transverse groove to the anterior margin of the prothorax. The *legs* do not differ from those of the male in any essential features. The *tarsal claws* are similar in both sexes and, in relation with the hind pair of legs, there are two ventral pads or *arolia* present on the first tarsal joint ("metatarsus") and a single such pad on the second tarsal joint (text-fig. 3).

The Abdomen has its dorsal surface more hairy than in the male, this feature being apparently correlated with the absence of wings. The tergal plates of the 8th and 9th segments are subequal in size, shorter than those of any of the preceding segments, and the 9th tergite, moreover, exhibits no asymmetry. The 10th tergum is somewhat longer than the 9th; it narrows posteriorly and the hind margin is prominently rounded (Pl. 38. fig. 1). The 8th sternum is the *subgenital plate.* It has a median transverse incision in its posterior margin, which marks the position of the *genital aperture* (*g.ap.* in Pl. 38. fig. 4). The sterna of the 1st and 8th segments are smaller than any of the remaining sterna. The 9th sternum varies from 2–2½ times the length of the 8th, and its posterior margin has a small shallow median notch. The 10th sternum, unlike that of the male, is divided longitudinally into two symmetrical plates ($st._{10}$ in fig. 4). The right and left cerci are similar to one another, and at the base of each cercus there is an annular vestige, which may possibly represent the *basal plate* *, present in relation with each cercus in the primitive genus *Clothoda*, Enderl., and well developed in most Embiid larvæ.

Coloration.—Dorsally the coloration varies from uniform dark brown to almost black, and in some lights it appears quite black. The intersegmental regions between the head and the prothorax, between the prothorax and mesothorax, and between the mesothorax and metathorax, are membranous, flexible, and whitish in colour. The pleural region commences from the basal half of the metathorax and extends backwards to the extremity of the 8th abdominal segment, and is similarly membranous. It appears as a prominent whitish line running along each side of the body, and visible dorsally as a pair of lateral streaks (Pl. 38. fig. 1). The antennæ are similar in colour to the head, with the articulations between the individual joints paler. The distal half of the clypeus (*ante-clypeus*), the labial and maxillary palpi, the region around the articulations between each of the joints of the legs, the two apical joints of the anterior tarsi, and the tibiæ and tarsi of the middle and posterior pairs of legs are lighter in colour than the rest of the body. The claws of the feet are yellowish-white with piceous apices, and the cerci are yellowish-white at their extremities. Ventrally the coloration is paler than dorsally, with a slight primrose tinge in many individuals. The sternum of the 8th, with the exception of its median portion, and the sterna of the 9th and 10th segments are darker in colour than those of the preceding abdominal segments.

* "Cercus basipodite" or "Grundplatte" of the German authors.

4. *A Table of Comparison of the Principal Differences between the Sexes.*

MALE.	FEMALE.
Winged.	*Wingless.*
Body-hairs brown-black or black, absent for the most part from the dorsal surface of the thorax and abdomen.	Body-hairs light brown, longer than in male, present to some extent on the dorsal surface of the thorax and abdomen.
Maximum length 18 mm.	Maximum length 20·75 mm.
Head, thorax, and abdomen related in length as 3 : 5 : 8.	Head, thorax, and abdomen related in length as 3 : 7 : 10.
Eyes reniform.	Eyes smaller, less markedly reniform.
Antennæ 6–7·5 mm. in length, longer than the thorax. Joints 20–29; the combined length of 4th–6th joints exceeds that of the first two joints.	Antennæ 5–6 mm. in length, shorter than the thorax. Joints 23–29; the combined length of 4th–6th joints less than that of the first two joints. All the joints shorter and more annular than in male.
Mandibles slender, biting-edge but little developed.	Mandibles massive, biting-edge armed with four prominent teeth.
Apical teeth of lacinia of 1st maxilla small.	Apical teeth of 1st maxilla larger and more prominent.
Thoracic segments short; the terga of the meso- and metathorax modified in correlation with the presence of wings.	Thoracic segments elongate; the terga of the meso- and metathorax simple and unmodified.
Abdomen consists of ten tergal and nine evident sternal plates.	Abdomen consists of ten tergal and ten sternal plates.
The 10th tergum divided into two asymmetrical shields. The 9th tergum also asymmetrical.	The 10th tergum undivided; both it and the 9th tergum symmetrical.
The 9th sternum enlarged and markedly asymmetrical. It is probably a composite structure formed by the right plate of the 10th sternum becoming fused with it. The left plate of the 10th sternum is probably represented by the "ventral process."	The 9th sternum not enlarged, symmetrical. The 10th sternum in the form of two symmetrical shields.
The basal joint of the left cercus much enlarged.	The basal joint of the left cercus not enlarged, similar to that of the right side.
The genital aperture terminal in position, the 9th sternum forming the subgenital plate.	The genital aperture ventral in position, the 8th sternum forming the subgenital plate.
The external genitalia formed by the curved process of the left shield of the 10th tergum and the "ventral process" attached to the 9th sternum.	External genitalia absent.

5. Systematic Position of the Species.

Embia major is more closely allied to *E. sabulosa*, Enderlein (Denskr. med. Naturw. Ges. Jena, Bd. 13, 1908, pp. 347–48, with 2 figs.), from South Africa, than to any other species of its genus. The male of *major* agrees with that of *sabulosa* in the form of the basal joint of the left cercus, in the absence of any evident process to the right plate of the 10th tergite, and in the completeness of the neuration of the wings, all the longitudinal veins attaining the wing-margin. The following characters, among others, readily separate the two species :—

E. major, Imms.	*E. sabulosa*, Enderlein.
Male measures 12·75–18 mm. in length. Female measures 14·75–20·75 mm. in length.	Male measures 7·5–8·5 mm. in length. Female measures 10–11 mm. in length.
Number of antennal joints varies from 20–29.	Number of antennal joints varies from 17–21.
10th abdominal tergite of the male completely divided into right and left plates. The process of the left plate short and very much curved.	In the male the line of division between the right and left plates of the 10th abdominal tergite does not quite extend back to the anterior margin of that segment. The process of the left plate long, and only slightly curved at its apex.
The 1st tarsal joint of the hind pair of legs provided with two ventral pads or *arolia* in both sexes.	The 1st tarsal joint of the hind pair of legs provided with a single arolium.

6. The Ova.

The eggs are oval in form, with a smooth and faintly glistening appearance, and are pale cream-white in colour. In average size they measure approximately 1 mm. in length and ·5 mm. in diameter. Below are recorded the actual measurements made on 21 eggs deposited by five different females :—

Length	1·07	1·17	1·05	1·05	1·12	1·22	1·15	1·10	1·07	1·05	1·17
Diameter	·55	·55	·55	·57	·65	·60	·55	·55	·52	·52	·65
Length	1·20	1·12	1·12	1·15	1·05	1·02	1·07	1·05	1·07	1·05	
Diameter	·55	·60	·52	·52	·55	·52	·55	·50	·55	·55	

It will be noted that the eggs vary from 1·02 mm.–1·22 mm. in length and from ·52 mm.–·65 mm. in diameter.

At one extremity of the egg is a large prominent operculum (Pl. 38. fig. 12). This operculum is broadly pyriform in shape, and where it comes in contact with the rest of the chorion there is a well-defined rim or margin. The general surface of the chorion is finely sculptured into a series of irregular hexagons. The diameter of these figures, measured between two opposite faces, varies between ·031–·05 mm. (fig. 10). Over the surface of the operculum the sculpturing is of a somewhat different character; it takes the form of a series of irregular polygonal areas bounded by very thick walls (fig. 9). The inside diameter of these areas, the measurements being taken between opposite faces, varies from ·012–·018 mm.

The number of eggs deposited by each female was found to vary from about 60 to 100. The eggs laid by eleven females, each inhabiting a separate nest, were counted, and their numbers were as follows:—59, 69, 70, 71, 73, 77, 79, 82, 97, 98, and 106 respectively. Oviposition takes place within the tunnels of the nests. In those instances where a nest is occupied by more than one female, the latter keep their eggs separate and apart from those of their companions. Each female deposits her eggs all together in an irregular heap loosely bound by fine silken threads. Additional threads also secure the eggs to the wall of the tunnel. The incubation period was found to vary from three weeks to one month, or a little longer, according to the prevailing climatic conditions.

Between June 20th and July 4th, I visited the locality where *Embia major* occurs, but after a prolonged search was unable to discover any eggs. On the latter date I had to leave the locality and travel to Dehra Dun. I brought along with me, in a small zinc breeding-cage, two females and two males. The insects were afterwards separated as two pairs, comprising a male and a female each, and placed in separate vessels along with some soil and clumps of grass. The vessels employed were a pair of crystallising dishes used by chemists, each dish being covered by a circular metal plate and kept in a moderately cool room out of the direct rays of the sun. These females commenced depositing their ova on July 9th and 10th. The first insect hatched out on August 1st, one hatched out on August 4th, three more on August 5th, and the remainder were all hatched by August 7th, the incubation period in these instances varying between 23 and 30 days. During the process of development the eggs did not undergo any change of colour. During the second week in August 1912, I again had occasion to visit the Naini Tal district, and devoted one afternoon (August 8th) to an examination of some thirty nests of this insect. In every nest females, along with their ova, were in evidence. Except in three nests, where a few first-stage larvæ were found, none of the eggs had hatched out. Dehra Dun is situated at the foot of the Himalayas, at an altitude of 2200 feet and has a correspondingly higher mean temperature. This higher temperature accounts for the captive larvæ emerging at an earlier date than in their usual habitat.

Four batches of ova were brought from Sat Tal, and from these eleven specimens of a new species of parasite of the family Scelionidæ, belonging to the genus *Embidobia*, Ashm., were bred out in Dehra Dun. This parasite, when it is about to emerge, eats its way out of the egg by gnawing a hole through the chorion, towards the end of the egg opposite to that which bears the operculum (Pl. 38. fig. 12).

During the incubation period the female *Embia* constantly guards her eggs, resting with them lying beneath her body. A more detailed account of this instinct is given on p. 189.

7. The Newly Hatched Larva.

The newly hatched larva is entirely white, with the exception of the eyes, which appear as a pair of purple-brown dots, and the brown strongly chitinised edges of the mandibles. On one occasion the larva was observed in the act of emerging from the egg. It issues head foremost and forces open the operculum, which remains attached along a small portion of its periphery to the remainder of the chorion (Pl. 38. fig. 12). In total length the newly hatched larva varies between 1·6 and 1·8 mm., the measurements being taken from the apex of the labrum to the extremity of the last abdominal tergite. It is a relatively specialised example of the Campodeiform type of larva, and exhibits no primitive features in its organisation which do not also occur in the female imago. The head, thorax, and abdomen are related in length in the proportion of 5 : 4 : 7 respectively. The most striking feature in the external morphology of the young larva is the relatively great size of the head; it is ovoid, and exceeds the thorax both in length and diameter (Pl. 37. fig. 7). The head, body, and appendages are clothed with rather long thinly-distributed hairs. The antennæ are 9-jointed, and as long as or a little longer than the abdomen. The thoracic segments are extremely simple in character, and are much shorter in proportion to their breadth than in the adult. There is no marked indication of the transverse suture of the prothorax, which is a prominent feature in the adult insect. The legs are remarkably large, and the hind pair when extended backwards reach to a little beyond the apex of the abdomen. They differ very little in form from those of the adult, both the enlarged first joint of the fore tarsi and the swollen hind femora being evident. The abdomen consists of nine apparent segments, the ninth and tenth segments not being completely differentiated from one another. The cerci are two-jointed; the basal joint is very small and annular, and measures only one-eighth of the length of the second joint. The larvæ are all similar to each other, no external traces of sexual differentiation being noticeable. When removed from the protection of the parent, the young larvæ were observed to weave delicate tunnels within a few hours after emergence from the egg.

8. The Second-Stage Larva.

In larvæ measuring from 3–3·5 mm. in length, certain differences are noticeable, and by which they are readily distinguished from the newly hatched larva. At this stage in post-embryonic development the larva was from 21–23 days old. It is pale pinkish brown in colour, with the head and the margins of the thoracic and abdominal segments somewhat darker. The appendages and the whole of the ventral surface of the animal are pale and very little pigmented. The head no longer dominates the rest of the body, it being shorter than the thorax. The antennæ are 12-jointed, shorter in length than the abdomen, and only a very little longer than the thorax. The thorax has increased very much in length, and the transverse suture of the prothorax is completely formed. The head, thorax, and abdomen are mutually related in length in the proportion of 5 : 7 : 10. The legs have grown comparatively little, and the posterior pair when extended can no longer reach to the apex of the abdomen. There are ten evident abdominal segments, and the 10th sternum is longitudinally divided into two lobes. The mouth-parts closely resemble those of the adult in their general structure. The mandibles are stout and broad, but partake more of the characters of those of the female than the male.

9. The Half-grown Larva.

During the beginning of December the larva has passed through the first half of its life. Measurements of these half-grown larvæ were made, and their length was found to average 9 mm. The antennæ at this period have 21 joints, and are of equal length to the thorax. In colour the larvæ are chestnut-brown, with the appendages and ventral surface pale. I was not able to detect any external sexual differences among larvæ of this age. Ten abdominal segments are present, and the last sternum is longitudinally divided into a pair of symmetrical plates. These persist throughout life in the female insect, but are no longer evident in the male at the close of the nymphal period. The basal plates of the cerci are relatively large and well developed. They are covered by the 10th tergal shield and are consequently not visible dorsally. They are in contact with one another on the mid-ventral line, and appear to be serially homologous with the paired plates of the 10th sternum already referred to. That they are to be regarded as the representatives of an 11th somite was first suggested by Enderlein (1903, p. 430).

The mouth-parts do not differ in any details, except in size, from those of the younger larva. During the cold weather months up to March, the half-grown larva undergoes very little growth, and remains to a large extent dormant. Individuals extracted from their tunnels were observed to be much longer, and more sluggish over the construction of new tunnels than they are at other periods in their life-history.

10. The Male Nymph.

The nymphal condition in the male is characterised by the presence of wing-rudiments, otherwise it only differs from the larva in its greater size. Its period of duration is about two months commencing during the first half of May, when the young insect is from 9–9½ months old. The youngest nymph observed measured 11·5 mm. in length, with wing-rudiments 1·25 mm. long. At the close of the nymphal instar, examples 15–17 mm. in length are frequent. A nymph 15 mm. long has wing-rudiments measuring 2·25 mm. in length.

Viewed dorsally, the body and appendages are light chestnut-brown in colour, the head and the extremity of the abdomen being slightly darker than the rest. Ventrally the insect is of a much paler colour. The number of antennal joints varies from about 23–25, and correlated with the development of the wing-rudiments the tergal plates of the meso- and metathorax have assumed their triangular form seen in the fully-fledged adult.

The asymmetrical condition of the cerci and apical abdominal segments in the male is acquired very late in development, and for this reason is probably a phylogenetically recent acquisition. In the early nymph no indications are apparent at all (Pl. 37. figs. 5 & 6), but in a fully-grown nymph the 10th tergite of the adult is clearly visible beneath the cuticle. It has undergone division into two unequal plates, which are seen in process of development (Pl. 37. fig. 4). Unlike the adult male, the nymph possesses ten abdominal sterna. The 1st sternum is much reduced and soldered to the posterior margin of the metathorax. The remaining sterna differ but little from their condition in the adult, excepting those of the two terminal segments (Pl. 37. fig. 6). The 9th sternum is still unmodified, and exhibits no traces of asymmetry. The 10th sternite resembles that of the adult female in being longitudinally divided into two similar shields (*st.* 10 in fig. 6). The 9th and the right plate of the 10th sterna subsequently become fused to form the large asymmetrical *subgenital plate.* In relation with the base of each cercus are two *basal plates* (*b.p.* in Pl. 37. fig. 6).

The mandibles differ from those of the adult male in being relatively stouter and more massive, and resemble closely those of the female.

11. The Female Nymph.

A nymphal instar in the female can scarcely be said to exist. It is indistinguishable from the larva except in point of size and in the development of the genital aperture. It, furthermore, only differs externally from the adult in being paler in colour (light pruinose or chestnut-brown) and with the cuticle less chitinised. The largest female nymph measured 19·25 mm. long, and had 23 joints to the antennæ.

12. Observations on the Biology of the Species.

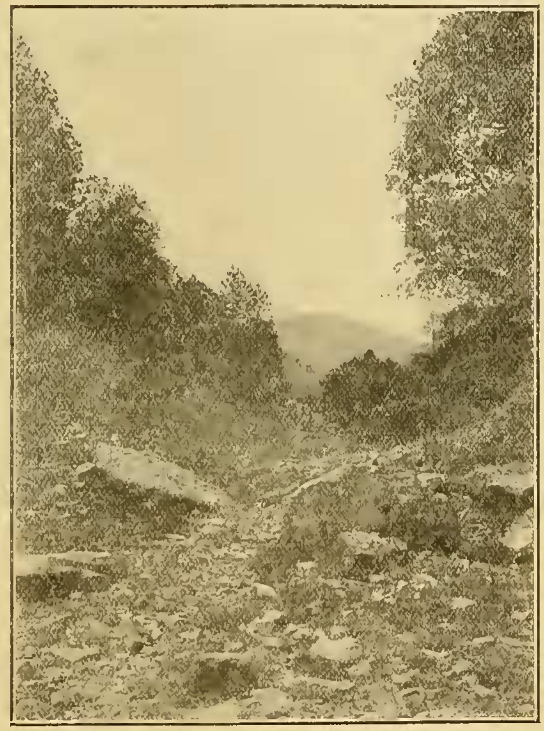
The nests of *Embia major* were only met with in a restricted area between the village or "basti" of Bhowali and the Sat Tal lakes, in the Naini Tal district of the Kumaon Himalaya. Sat Tal is one of a series of five lakes or "tals" found in this district of Kumaon. According to Theobald they owe their origin to obstructions in the local drainage caused by the débris of old moraines when the glaciers receded at the close of the glacial epoch *. The name Sat Tal means "seven lakes," and in former times seven small lakes actually existed. At the present day, however, only two lakes of appreciable size remain, and the larger of these, Sat Tal proper, is situated at an altitude of 4500 feet above sea-level. The nests of the *Embia* were found at elevations varying between about 4900 and 5100 feet, and $1\frac{3}{4}$ miles distant from the lake. They occurred under loose flat pieces of stone which lie scattered in the form of débris over a hill-side and open valley (text-fig. 5). Such situations are neither very dry nor very moist. The area within which *Embia* was found is very thinly forested, and the trees consist for the most part of "chir" pine (*Pinus longifolia*), Himalayan oak (*Quercus incana*), and *Rhododendron arboreum.* Flat stones were selected almost without exception as the sites for the nests. Between the lower surface of such stones and the ground, the Embiids weave the silken tunnels which form their nests. The shape of the nests depends upon the form, length, and number of these tunnels. In eight nests the ground beneath such stones was found to be occupied both by the *Embia* and an undetermined species of Termite. The tunnels of the Termite were alongside and in close contact with those

* Theobald, "The Kumaon Lakes." Rec. Geol. Survey India, xiii. 1880, p. 161.

of the *Embia*. It is noteworthy that the two species of insect appeared to be on perfectly amicable terms with one another, resembling symbiosis. Furthermore, it may be mentioned that Wasmann (1904, p. 17) records an Embiid, *Oligotoma termitophila*, occurring in nests of *Termes natalensis* in the Soudan.

The restricted distribution of the *Embia* is difficult to account for, especially as apparently similar localities are plentiful in the surrounding country. Altogether 211 nests of the species were met with, and they occurred over an area about 1½ miles in length. An examination of 130 nests was made with the object of obtaining information with regard to number of individuals inhabiting each nest, and the relative

Text-fig. 5.



A. D. Imms Photo.

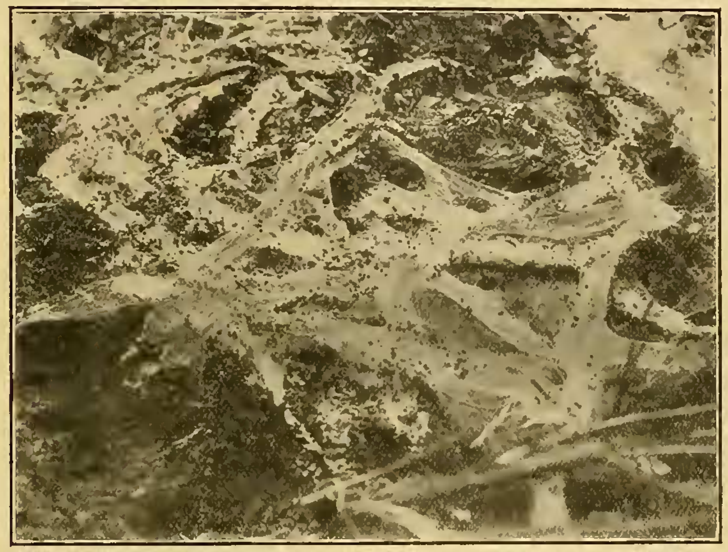
View near Sat Tal, Kumaon. The nests of *E. major* occur under the stones scattered along the valley and hill-side. (Westwood Bequest.)

proportions of the sexes. Contrary to what would be anticipated from previous observations on Embiidæ, the female was found to be of much more frequent occurrence than the male. From an examination of 130 nests, made from June 27th until July 3rd, 88 of them (or 67·6 per cent.) were found to contain females only, 30 nests (or 23 per cent.) contained both males and females, while 12 nests (or 9·2 per cent.) contained male individuals only. From these figures it will be noted that males were only found in 32 per cent. of the nests that were examined. Some 268 individuals were found inhabiting these 130 nests (*vide* table on p. 188), and of these 109 (or 40 per cent.) were males and 159 females. This relatively high percentage among the males is somewhat remarkable, and is mostly owing to the fact that three nests (nos. 68, 89, and 125) contained no fewer than 39 male individuals among them; in no other instances were more than five males found in a single nest. The females have a marked tendency to be solitary, which is indicated by the fact that 73 nests, or 61 per cent. of the total number examined, contained single individuals only. In the cases of the males this tendency does not appear to be evident. Out of 42 nests containing males, in only 9 (or 14 per cent.) were single specimens found.

The form assumed by the nests is very variable (Pl. 36). As a general rule, at least three secondary or side tunnels are constructed, and these communicate with the larger main tunnels of the nest. Certain of the side tunnels serve as entrance or exit passages, while others terminate blindly. In most nests there is usually a hole or aperture present, leading from one of the tunnels into the ground. This hole is the entrance to a subterranean passage or chamber (*u.c.* in Pl. 36); in some instances this chamber was found to be lined with silk, while in others no silk was present. When disturbed the occupants of a nest frequently take refuge in these subterranean passages, but it is by no means always the case. I believe that their primary function is that of a place of retreat during the dry hot weather. The nests further vary very much in size, and this to a large extent depends upon the number of occupants therein. In the case of nests inhabited by a single individual, or in some cases two individuals, only one or two elongate tunnels of loosely woven silk are constructed, and the contained Embiids show clearly from within. In those instances where several Embiids exist in association with one another, they all participate in the formation of a common nest. The latter then assumes the form of a somewhat complex meshwork of tunnels. In the most complex nests a series of superposed tunnels is present, the lowest layer extending for a short distance into the earth. Such nests are the result of the combined efforts of a large number of occupants. Much more silk is expended on their construction, and the walls of the tunnels are denser and whiter in appearance. A typical large nest is shown in text-fig. 6. The largest number of individuals found inhabiting any single nest was 21. Nest no. 47 (Pl. 36. fig. 2) contained four females and one male, and measured 1 foot 4 inches in length. Nest no. 20 (fig. 3) contained a single female only, and was exceptionally large for the work of one individual; it measured $11\frac{1}{4}$ inches in greatest length and $5\frac{1}{2}$ inches in maximum width. Nest no. 26 (fig. 4) contained one male and one female. Nest no. 39 (fig. 5) contained two females; and nest no. 85 (fig. 8) contained one male, one female, and one immature male.

The first step in the construction of a nest consists in the spinning of a tolerably straight silken tunnel about 3 or 4 inches in length (fig. 1), and many nests occupied by single individuals remain in this simple condition. From a reference to the table given on p. 188, it will be noted that nests nos. 68, 76, 89, and 125 contained 21, 10, 19, and 12 occupants respectively. Such nests attain a relatively high degree of complexity (*vide* text-fig. 6). The various individuals contribute towards the construction of these large nests, and exhibit in this respect something more than a simple gregarious instinct. I regard these nests as a manifestation of an incipient tendency to colony formation, which has undergone little or no evolutionary development. Captive Embiids, when placed in a glass phial together, do not weave separate and distinct tunnels, but manufacture one common structure which shelters them all. This faculty of producing silk is developed equally in both sexes. When a nest is disturbed the occupants run rapidly along the tunnels either in a forward or backward direction with equal facility, and frequently take refuge in the underground chamber already referred to. Sometimes when much disturbed they desert their nests and take shelter under neighbouring stones or in surrounding herbage. They are capable of running very rapidly along the ground,

Text-fig. 6.



A. D. Imms Photo.

A large and complex nest (no. 76) showing the superposed series of tunnels. The nest was inhabited by ten individuals. The minute black particles overlying the tunnels are the excrementa or "frass" ejected by the insects. (A little less than one-half natural size.) (Westwood Bequest.)

but in no instance did the males make any attempt to take refuge in flight. In habits they are most probably exclusively nocturnal. Although the herbage was explored by sweeping, no individuals were met with in the daytime outside the nests.

From frequent observations I believe that the primary function of the silken tunnels of the Embiidæ is protective. Any predaceous insect which attacks the *Embia* while within the walls of its tunnel becomes entangled in the silken threads of the latter, allowing the *Embia* to make good its escape. Grassi and Sandias (1897, p. 64) consider that these tunnels serve to protect the body from too excessive transpiration, and to retain about the *Embia* an atmosphere not too dry. It is difficult, however, to imagine what difference these delicate tunnels could make in this respect—for instance, during the intensely hot weather that prevails from March to June in the Punjab and United Provinces. At such times of the year the amount of humidity in the air is negligible;

TABLE showing the number of individuals and the proportion of the sexes in 130 nests of *Embia major*.

Nest Number.	Males.		Females.		Total	Nest Number.	Males.		Females.		Total	Nest Number.	Males.		Females.		Total
	Adult.	Immature.	Adult.	Immature.			Adult.	Immature.	Adult.	Immature.			Adult.	Immature.	Adult.	Immature.	
1	..	1	..	..	1	46	..	..	1	..	1	91	..	..	2	..	2
2	..	1	1	..	2	47	1	..	4	..	5	92	..	..	1	..	1
3	1	..	..	..	1	48	..	..	2	..	2	93	..	..	1	..	1
4	..	..	1	..	1	49	..	..	1	..	1	94	1	1	1	..	3
5	..	..	1	..	1	50	3	..	..	..	3	95	..	..	1	..	1
6	..	..	1	..	1	51	1	..	..	..	1	96	..	..	1	..	1
7	..	..	1	..	1	52	..	..	1	..	1	97	..	..	1	..	1
8	..	..	1	..	1	53	..	..	1	..	1	98	..	..	2	..	2
9	1	..	..	..	1	54	..	..	1	..	1	99	..	..	1	..	1
10	..	..	1	..	1	55	..	..	1	..	1	100	..	..	2	..	2
11	..	..	1	..	1	56	..	..	1	..	1	101	..	..	1	..	1
12	1	..	1	..	2	57	..	..	1	..	1	102	..	..	2	..	2
13	..	..	1	..	1	58	3	2	1	..	6	103	..	..	1	..	1
14	..	..	1	..	1	59	..	..	2	..	2	104	1	..	1	..	2
15	..	..	1	..	1	60	..	..	1	..	1	105	..	..	1	..	1
16	3	..	1	..	4	61	..	..	1	..	1	106	1	..	2	..	3
17	..	..	1	..	1	62	..	..	1	..	1	107	..	..	1	..	1
18	4	..	1	..	5	63	..	..	1	..	1	108	1	..	1	..	2
19	..	..	2	..	2	64	4	1	1	2	8	109	..	..	1	..	1
20	..	..	1	..	1	65	..	..	1	..	1	110	1	..	2	..	3
21	..	..	1	..	1	66	..	..	1	..	1	111	..	..	2	..	2
22	..	..	1	..	1	67	1	..	..	1	2	112	..	..	1	..	1
23	..	..	1	..	1	68	6	3	8	4	21	113	..	..	1	..	1
24	1	..	..	..	1	69	..	..	1	..	1	114	2	..	1	..	3
25	1	..	..	..	1	70	..	..	1	..	1	115	1	..	1	..	2
26	1	..	1	..	2	71	1	..	1	..	2	116	..	..	1	.	1
27	..	..	1	..	1	72	1	..	1	..	2	117	1	..	..	..	1
28	1	..	1	..	2	73	..	..	1	..	1	118	4	..	..	..	4
29	..	..	1	..	1	74	..	..	1	..	1	119	..	..	1	..	1
30	..	..	1	..	1	75	..	..	1	..	1	120	..	..	1	..	1
31	1	..	1	..	2	76	3	2	4	1	10	121	..	..	2	..	2
32	..	1	1	..	2	77	..	..	1	..	1	122	..	..	1	..	1
33	..	..	1	..	1	78	..	..	2	..	2	123	..	..	1	..	1
34	..	..	1	..	1	79	..	..	2	..	2	124	..	..	2	..	2
35	..	..	1	..	1	80	..	..	1	..	1	125	10	1	1	..	12
36	..	..	1	..	1	81	..	..	1	..	1	126	..	..	2	..	2
37	2	..	1	..	3	82	..	..	2	..	2	127	..	..	1	..	1
38	..	..	1	..	1	83	..	..	1	..	1	128	..	..	1	..	1
39	..	..	2	..	2	84	..	..	1	..	1	129	1	..	..	1	2
40	1	..	1	..	2	85	1	1	1	..	3	130	..	..	..	1	1
41	..	..	1	..	1	86	1	..	..	..	1						
42	..	..	1	..	1	87	2	..	3	..	5						
43	..	..	1	..	1	88	5	..	1	..	6						
44	1	..	..	..	1	89	17	2	..	..	19	Complete totals ...	93	16	149	10	268
45	..	..	1	..	1	90	..	..	1	..	1						

nevertheless Embiidæ flourish in those regions. Melander (1902, p. 22) believes that the tunnels probably serve merely as a retreat.

Individuals placed in captivity are at first agitated, but they very soon settle down and become seemingly adapted to new surroundings. On June 5th three females were taken from three separate nests and placed in a glass phial closed with a cork stopper. When examined two hours after capture they had spun a straggling silken tunnel and were reposing within it. On another occasion a captive male was observed to have already commenced manufacturing its tunnel within half an hour of its being captured. During the process of weaving these tunnels the fore-legs are in active motion, the insect at the same time occasionally turning about on the long axis of its body. In order to construct the roof of its tunnel it turns over on to its back, presenting its ventral surface towards the observer. Newly hatched larvæ, when removed from the proximity of the parent female, were observed to weave tunnels with equal facility to older individuals. Insects in the act of spinning were observed with the aid of a Zeiss binocular microscope, which allows of their movements being tolerably readily followed. The silk is extruded at the apices of long glandular hairs situated on the ventral surface of the enlarged first tarsal joint of the anterior pair of legs. These threads are extremely fine and can only be observed when the Embiids are retained in a glass vessel lined on the bottom with non-glazed black paper. The fact that a number of such threads are produced simultaneously accounts for the rapidity with which these insects weave their tunnels. I hope to publish in a later paper the results of a prolonged series of observations dealing with the much debated problem of the mechanism of silk production in the Embiidæ. A full discussion of this subject will be found in the memoirs of Grassi and Sandias (1898, Appendix II. p. 62), Rimsky-Korsakow (1910, p. 153), Krauss (1911, p. 15), and Enderlein (1912, p. 12).

Maternal care on behalf of the ova and young larvæ is strongly exhibited by the females, in very much the same manner as has been long known to occur among the Dermaptera from the observations of Frisch, De Geer, Xambeu, Green, and others. The female *Embia major* shows very marked solicitude for the welfare of her offspring after her first few eggs have been deposited. She takes up her position in close proximity to the ova and usually concealing them, so far as possible, by means of her body. If alarmed and driven away, she returns sooner or later to take up the same attitude. When the young larvæ are hatched they remain around the parent female, who conceals them, so far as she is able, by means of her body, very much after the same manner as a hen guarding her brood of chickens. A female and her brood were kept in a small glass trough and observed daily living in intimate association. When separated from the parent the larvæ were observed the next day to have regained their former position. As the larvæ approach their second stage in growth (p. 182), they exhibit a tendency to wander away from the female and construct small tunnels for themselves. They are markedly social, the whole of a brood living together within a complex silken meshwork of tubes.

Embia major was found to be both easy to rear and observe in captivity. Females were kept in crystallising dishes such as are used by chemists, and measuring 10 inches in diameter. A layer of fine earth, after being carefully sifted and examined for other insects. Arachnids, &c., was spread for a depth of half an inch on the bottom, and a lid of metal was placed on the top to prevent the Embiids from making their escape. In this simple contrivance the females laid their eggs and the young brood developed to maturity. The only dangers to be guarded against are mould and too great an amount of dryness. The moisture sufficient for their welfare was afforded by lightly distributing some fresh grass (pulled up along with the roots) over the surface of the soil in the vessel. This device, furthermore, prevented the development of mould. The grass was changed once a week during the cold weather and hot weather seasons, and once a fortnight during the monsoon season. The females were found to be vegetarian in diet and thrived on the grass supplied, no animal matter of any kind being given to them. When enclosed in glass tubes they eat their way very readily through the cork stoppers and escape. Whether the male is carnivorous, as has been suggested by Friedrichs (1906) in the case of European species, I am unable to say. The great differences in the structure of the mandibles in the two sexes certainly supports Friedrich's suggestion. Those of the male are slender and devoid of any crushing-edge, and in this respect bear a considerable resemblance to those of carnivorous insects. On the other hand, I have reared the insect from the egg-stage up to the nymphs of both sexes entirely on vegetable food. It is a remarkable fact, however, if the male imago alone is carnivorous. This point is certainly in need of further investigation, which I hope to pursue at a subsequent opportunity.

The females lived in captivity for $6\frac{1}{2}$ months after oviposition; the males, however, only survived for a short time after the eggs had been laid.

The complete life-history of the insect may be summarised as follows:—

Life-history of *Embia major* as observed in the Kumaon Himalayas during the years 1910–12.

Cold Weather Season.			Hot Weather Season.			Monsoon Season.			Cold Weather Season.		
January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
						○○○	○○				
●●●●	●●●●	●●●●	●●●●	●●			●●●●	●●●●	●●●●	●●●●	●●●●
				⊕⊕⊕	⊕⊕⊕⊕	⊕⊕					
					♀♀	♀♀♀♀	♀♀♀♀	♀♀♀♀	♀♀♀♀	♀♀♀♀	♀♀
					♂♂	♂♂♂♂	♂♂♂♂				

○ = Egg Stage; ● = Larval Period; ⊕ = Nymphal Period; ♀ = Period of Female Imago; ♂ = Period of Male Imago.

In this table it will be noted that the signs are grouped in fours, representing the weeks in each month. As an example, it will be seen that the earliest date the eggs were found is the second week in July, and that they have been met with up to the second week in August. Similarly, the earliest observed date of the emergence of the larva is the first week in August, and so on.

Expressed in a few words, it may be said that during the monsoon season the eggs are laid and early larval development takes place. It is, furthermore, a period of rapid growth. During the cold weather months growth is comparatively slow, and the larva for a portion of the time remains partially dormant. In the hot weather season growth takes place more rapidly than at any other time. During this period the larval stage is completed, the nymphal condition passed through, and the imaginal state attained—all taking place within a period of approximately two months.

13. Summary of Conclusions.

Embia major, sp. nov., is the largest species of Embiidæ hitherto discovered, and the first member of its genus to be found within the limits of the Oriental zoo-geographical region. It is more closely related to *E. sabulosa*, End., from South Africa than to any other species.

It occurs plentifully under pieces of stone scattered over a hill-side and an open valley in the Naini Tal district of the Kumaon Himalayas, such situations being neither very dry nor very moist. It is very local and occurred between elevations of 4900 and 5100 feet.

Females are more prevalent than males. Some 130 nests were examined and 67 per cent. contained females only, 23 per cent. contained individuals of both sexes, and 9 per cent. males only.

The nests are very variable in form and composed of a network of silken tunnels. The silk is produced by glands situated in the enlarged tarsal joint of the anterior pair of legs. The faculty of weaving nests is possessed equally by both sexes, and also by the larvæ and nymphs.

The size of the nests depends to a large extent upon the number of individuals inhabiting them. The largest number of individuals found in a single nest was 21. Where several individuals are associated together in a nest it is to be regarded as the manifestation of an incipient tendency to colony formation, which has undergone little or no evolutionary development.

Maternal care on behalf of the ova and young larvæ is strongly exhibited by the females, in very much the same manner as occurs among Dermaptera. The female lives for at least 6½ months after fertilisation; the male, however, is much shorter lived.

The eggs measure 1 mm. long and ·5 mm. broad; they are oval, cream-white, and have a smooth, faintly glistening appearance. The number of eggs laid by a single female varies between about 60 and a little more than 100. They are laid during July and August in the monsoon season, and are placed in an irregular heap within one of the silken tunnels of the nest.

The incubation period of the eggs varies between about 23 and 30 days. They are parasitised by a minute Hymenopteron of the genus *Embidobia*, Ashm., family Scelionidæ.

The newly hatched larva is 1·6 mm.–1·8 mm. long, and entirely white, with the exception of the eyes and the strongly chitinised apices of the mandibles. It is a relatively specialised example of the Campodeiform type of larva, and exhibits no primitive features which do not also occur in the female imago. The chief characteristics are the relatively great size of the head, nine evident abdominal segments, and 9-jointed antennæ. The enlarged 1st joint of the anterior tarsi is present as in the imago.

Larval growth consists chiefly in increase in size, increase in the length of the abdomen, the adding of numerous joints to the antennæ, and the darkening of the coloration. The larval period lasts from the end of July or the beginning of August until the following May.

The nymph stages last about two months during May, June, and July. The female nymph does not differ from the adult except in colour and degree of chitinisation. The male nymph is chiefly characterised by the presence of wing-pads.

The characteristic asymmetry of the terminal abdominal segments of the adult male is acquired very late in development, not being evident until the end of the nymphal period. For this reason it is probably a phylogenetically recent acquisition. In the larvæ, the female, and the nymphs of both sexes a well-defined 10th sternum, consisting of a pair of symmetrical plates, is present. The subgenital plate of the adult male is probably formed by the fusion of the right 10th sternal plate with the 9th sternum, the left 10th sternal plate persisting as the "ventral process."

A study of the wing-neuration shows a remarkable degree of variation, no two specimens being identical. Many of the variations are reversions to a generalised state exhibited in more primitive genera.

The larvæ, nymphs of both sexes, and females are vegetable feeders, and the mandibles of the larvæ and nymphs closely resemble those of the females; they differ from those of the male in being much stouter and provided with a crushing-edge. The possibility of the male alone being carnivorous requires further research.

14. Bibliography.

Comstock, J. H., & Needham, J. G. (1898).—The Wings of Insects. Amer. Nat. vol. xxxii. pp. 423–424.

Enderlein, G. (1903).—Ueber die Morphologie, Gruppierung, und systematische Stellung der Corrodentien. Zool. Anz. Bd. xxiv. pp. 423–37.

—— (1909).—Die Klassification der Embiiden, nebst morphologischen und physiologischen Bemerkungen, besonders über das Spinnen derselben. Zool. Anz. Bd. xxxv. pp. 166–91, 3 figs.

—— (1912).—Embiiden. In:—Collections Zoologiques du Baron Edm. de Sélys-Longchamps, Fasc. iii. No. 5, pp. 1–121, pls. 1–4, and 76 text-figs.

Friedrichs, K. (1906).—Zur Biologie der Embiiden. Neue Untersuchungen und Uebersicht des Bekannten mit Beitragen über die Systematik und Postembryonalen Entwicklung mediterraner Arten. Mitt. Zool. Mus. Berlin, iii. pp. 213–40, with 19 text-figs.

—— (1907).—Zur Systematik der Embiiden. Verh. zool.-bot. Ges. Wien, Bd. lvii. pp. 270–75.

GRASSI, B., & SANDIAS, A. (1897–98).—The Constitution and Development of the Society of Termites: Observations on their Habits; with Appendices on the Parasitic Protozoa of the Termitidæ, and on the Embiidæ. Quart. Journ. Micr. Sci. vol. xl. pt. I. pp. 55–75, pl. 19 (in vol. xxxix.). (English translation by W. F. H. Blandford of the original memoir in Atti Accad. Gioen. Catania, 1894.)

HAGEN, H. (1885).—Monograph of the Embidina. Canadian Entom. vol. xvii. pp. 141–155, 171–178, 190–199.

KRAUSS, H. A. (1911).—Monographie der Embien. Zoologica, Bd. xxiii. Heft 60, pp. 1–78, pls. 1–5, and 7 text-figs.

KUSNEZOV, N. J. (1904).—Observations on *Embia taurica*, Kusnezov (1903), from the southern coast of the Crimea. Horæ Soc. Entom. Ross. Bd. xxxvii. pp. 138–73. (In Russian, but with an abstract in English, pp. 166–69.)

LUCAS, H. (1859).—Quelques remarques sur la propriété que possède la larve de l'*Embia mauritanica* sécréter une matière soyeuse destinée à construire des fourreaux dans lesquels elle subit ses divers changements de peau. Ann. Soc. Ent. France, Sér. 3, Tome vii. pp. 441–444.

MACLACHLAN, R. (1877).—On the Nymph-stage of the Embidæ, with notes on the habits of the Family. Journ. Linn. Soc. Lond., Zool. vol. xiii. pp. 373–84, pl. 21.

MELANDER, A. (1902).—Two new Embiidæ. Biol. Bull. vol. iii. pp. 16–26, with 4 text-figs.

—— (1903).—Notes on the Structure and Development of *Embia texana*. Biol. Bull. vol. iv. pp. 99–118, with 6 text-figs.

PERKINS, R. C. L. (1897).—Notes on *Oligotoma insularis*, McLachl. (Embiidæ), and its immature conditions. Entom. Month. Mag. vol. xxxiii. pp. 56–58.

RIMSKY-KORSAKOW, M. (1905).—Beitrag zur Kenntnis der Embiiden. Zool. Anz. Bd. xxix. pp. 433–42, with 6 text-figs.

—— (1910).—Ueber das Spinnen der Embiiden. Zool. Anz. Bd. xxxvi. pp. 153–56, with 2 text-figs.

SAUSSURE, H. DE (1896).—Note sur la tribu des Embiens. Mitt. Schweiz. Entom. Ges. Bd. ix. pp. 339–55, 1 pl. (For a summary *vide* Zool. Centralbl. 1896, p. 697.)

VERHŒFF, K. W. (1904).—Zur vergleichenden Morphologie und Systematik der Embiiden, zugleich 3ter Beitrag zur Kenntnis des Thorax der Insekten. Acta Acad. Cæs. Leop.-Carol. Halle, lxxxii. pp. 145–205, Taf. 4–7.

WASMANN, E. (1904).—Termitophilen aus dem Sudan. Res. Swed. Zool. Exp. White Nile 1901, No. 13, pp. 17–20, Taf. 1. fig. 6.

WESTWOOD, J. O. (1837).—Characters of *Embia*, a genus of Insects allied to the White Ant (Termites), with a description of the species of which it is composed. Trans. Linn. Soc. Lond. vol. xvii. pp. 369–374, pl. 11.

WOOD-MASON, J. (1883).—A Contribution to our Knowledge of the Embiidæ, a family of Orthopterous Insects. Proc. Zool. Soc. Lond. pp. 628–34, pl. 56.

EXPLANATION OF THE PLATES.

Reference Lettering.

abd. .... Point of attachment of abductor muscle.
a.cl. .... Ante-clypeus.
add. .... Point of attachment of adductor muscle.
b.j. .... Modified proximal joint of left cercus.
b.p. .... Basal plate of cercus.
car. .... Cardo.
cl. ...... Clypeus.
cond. .. Condyle.
g. ...... Outer lobe or paraglossa of 2nd maxilla (labium).
gal. .... Galea.
g.ap. .... Female genital aperture.
ging. .... Ginglymus.
l. ...... Inner lobe of 2nd maxilla (labium).
lac. .... Lacinia.
lb. ...... Labrum.
l.p. .... Labial palp (left).
l.tg.$_{10}$ .. Left plate of 10th tergite.
m.$_{1}$ .... Mentum.
m.$_{2}$ .... Submentum.
mp. .... Median plate.
mx.p. .. Maxillary palp.
p.cl. .... Post-clypeus.
pgr. .... Rudiment of palpiger.
pl. .... Pleuron.
rt.g.$_{10}$ .. Right plate of 10th tergite.
st. ...... Stipes.
st.$_{7}$ .... Seventh sternite.
st.$_{8}$ .... Eighth do.
st.$_{9}$ .... Ninth do.
st.$_{10}$ .... Tenth do.
tg.$_{1}$ .... First tergite.
tg.$_{8}$ .... Eighth do.
tg.$_{9}$ .... Ninth do.
tg.$_{10}$ .... Tenth do.
tr.$_{1}$ .., *tr.*$_{2}$ .. } Arolia of 1st tarsal joint ("metatarsus").
tr.$_{3}$ .... Arolium of 2nd tarsal joint.
u.c. .... Entrance to underground chamber.
v.p. .... Ventral process of 9th sternum.
v.r.tg.$_{10}$.. Ventral aspect of right plate of 10th tergite.

Plate 36.

The figures on this plate are from rapid pencil-sketches drawn from Nature out in the field. They represent the various types of nests made by *Embia major*, and are rather smaller than natural size. The nest numbers refer to those enumerated in the table on p. 188.

Fig. 1. The simplest form of nest, consisting of a single tunnel and no underground chamber. Nest no. 6.
2. A complex type of nest, containing two underground chambers. The total length of this nest was 1 foot 4 inches. Nest no. 47.
3. A relatively large nest of simple construction, measuring $11\frac{1}{4}$ inches in length and $5\frac{1}{2}$ inches in breadth. Nest no. 20.
4. A small nest without an underground chamber. Nest no. 26.
5. A very usual type of small nest. Nest no. 39.
6. A simple branched nest with no underground chamber. Nest no. 35.
7. A simple "looped" nest with underground chamber. Nest no. 29.
8. A small much branched nest without an underground chamber. Nest no. 85.
9. A small branched nest with underground chamber. Nest no. 110.
10. A relatively complex type of nest, containing a long underground chamber lined with silk and provided with two entrances.

Plate 37.

With the exception of figs. 1 and 4 all were first drawn in outline with the aid of an Abbe drawing apparatus.

Fig. 1. An adult male viewed dorsally. × circa $5\frac{1}{2}$.
2. The apex of the ventral aspect of the abdomen in the adult male. × 16.
3. The apex of the dorsal aspect of the abdomen in the adult male. × 16.
4. A fully grown male nymph. The unequally divided 10th tergite of the adult is seen showing through the nymphal cuticle. × 7.
5. The apical three abdominal segments of a young male nymph seen from the dorsal aspect. × 16.
6. The apex of the abdomen of a young male nymph seen from the ventral aspect. The pair of small plates representing the 10th sternite are clearly visible. × 16.
7. A newly hatched larva seen from the dorsal aspect. × circa 38.

Plate 38.

With the exception of fig. 1 all were first drawn in outline with the aid of an Abbe drawing apparatus.

Fig. 1. An adult female viewed dorsally. × circa $7\frac{1}{2}$.
2. The first six joints of the left antenna of the male. (From a preparation mounted in Canada balsam.) × 28.
3. The first six joints of the left antenna of the female. (From a preparation mounted in Canada balsam.) × 28.
4. The last four abdominal segments of the adult female seen from the ventral side. × 10.
5. Left mandible of the male. (From a specimen mounted in Canada balsam.) × 28.
6. Left mandible of the female. (From a specimen mounted in Canada balsam.) × 28.
7. The 2nd maxillæ (labium) of the male seen from the ventral (external) surface. (From a specimen mounted in Canada balsam.) × 28.
8. The labium and clypeus of the male. The dotted line marks the division between the membranous *ante-clypeus* and the more strongly chitinised *post-clypeus*. (From a specimen mounted in Canada balsam.) × 28.
9. A portion of the surface of the operculum of the egg showing the sculpturing of the chitin. (From a specimen mounted in Canada balsam.) × 103.
10. A portion of the general surface of the chorion of the egg showing the sculpturing of the chitin. (From a specimen mounted in Canada balsam.) × 103.
11. The right 1st maxilla of the male. (From a specimen mounted in Canada balsam.) × 28.
12. A group of four eggs showing the fine silken threads that bind them together. The young larva has emerged from the egg on the left, and a portion of the egg membrane is seen attached to the operculum. The two eggs in the middle of the group have not yet hatched. The egg on the right shows the exit hole made by a minute egg-parasite of the family Scelionidæ and belonging to the genus *Embidobia*, Ashm., or a closely allied form. × 37.
13. The claws of the right middle leg of the adult male. (From a specimen mounted in Canada balsam.) × 51.